ION BEAM IRRADIATION OF COPPER NITRIDE: THE NITROGEN DEPLETION MECHANISM

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Introduction

Copper nitride is a metastable material which results very attractive because of their potential to be used in functional device. Cu_3N easily decomposes into Cu and N_2 by annealing [1] or irradiation (electron, ions, laser) [2, 3].
Previous studies carried out in N-rich Cu_3N films irradiated with Cu at 42MeV evidence a very efficient sputtering of N whose yield (5×10^3 atom/ion), for a film with a thickness of just 100 nm, suggest that the origin of the sputtering has an electronic nature. This N depletion was observed to be responsible for new phase formation (Cu_2O) and pure Cu [4].

Objectives

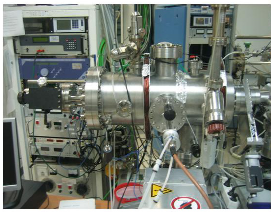
Our present aims are:

- To elucidate the responsible mechanism for the nitrogen losses.
- To determine the stopping power threshold for N depletion

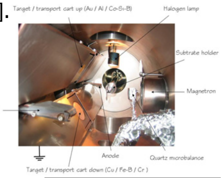
Experimental Description

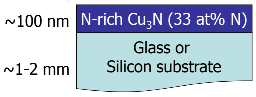
Samples deposition: DC Triode Sputtering

Polycrystalline N-rich Cu_3N films with a thickness of ~100 nm were deposited by DC-triode sputtering from a Cu target in the presence of a N_2+Ar atmospheres [5].



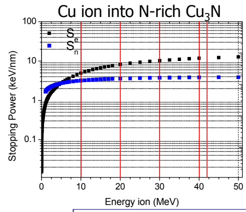
Sputtering chamber at the IMM/CSIC

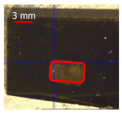




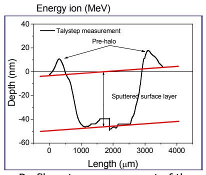
Ion beam modification and characterization

- ➢ Samples were irradiated with Cu ions at different energies from 42 MeV (Se = 12.48 keV/nm) to 10 MeV (Se = 4.93 keV/nm).
- ➢ At fluences from 4×10^{11} ion/cm² up to 4.5×10^{14} ion/cm², covering from the single ion track to the overlapping track regime.
- ➢ Some of the samples were irradiated with Cu at 42 MeV at different substrate temperatures (100 ºC<T<300 ºC).
- ➢ Nitrogen depletion is monitored by means of IBA techniques (NRA and ERDA).





Irradiation spot
(Φ= 4×10^{13} cm^{-2})

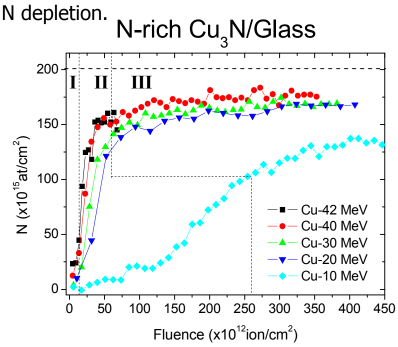


Profilometry measurement of the height of the beam spot profile

Results

N depletion: influence of stopping power (S)

The characterisation of N depletion as a function of stopping power allows determining the S threshold for N depletion.

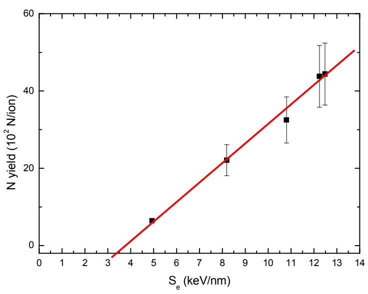


Three regions can be distinguished in the process of nitrogen escape:

Region I: The N content is almost constant⇨the migration and N_2 formation might be hampered by N trapping

Region II: High N sputtering rate which rapidly increase with rising S⇨ N migration > N trapping

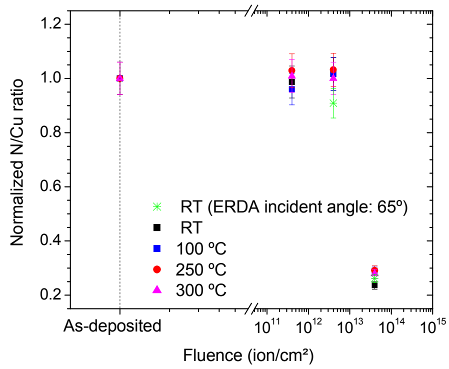
Region III: No N depletion is observed ⇨ The N content in the sample is almost exhausted



- Yield strongly increases with Se beyond a threshold value of 3.5 KeV/nm
- $Y_{measured}$ >> 0.16 N/at for Cu@42 MeV (calculated with SRIM)

Electronic processes

N depletion: influence of the substrate Temperature during irradiation



- No dependence of nitrogen depletion on the substrate temperature during irradiation is observed.
- These data cannot be properly explained on the basis of any of the existing thermal spike models [7, 8] because any of them would predict a significant track radius enhancement with increasing irradiation temperature, which would result in an increase in the nitrogen sputtering rate ⇨ but they can be better explained by considering the **excitonic model**.

Conclusions

- ➢ A high N depletion yield has been observed at intermediates radiation fluence.
- ➢ The number of N sputtered atoms very strongly increases with rising the electronic stopping power.
- ➢ The N depletion has been demonstrated not to depend on substrate temperature during irradiation.
- ➢ A stopping power threshold of 3.5 KeV/nm is determines for N depletion. This results is very important since it can be extrapolated to other irradiation techniques such as laser.
- ➢ All the data point out that the N depletion mechanism has an electronic nature and the excitonic model might account for the experimental observations.

References

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